



Integrating Safety and Mission Assurance in Design

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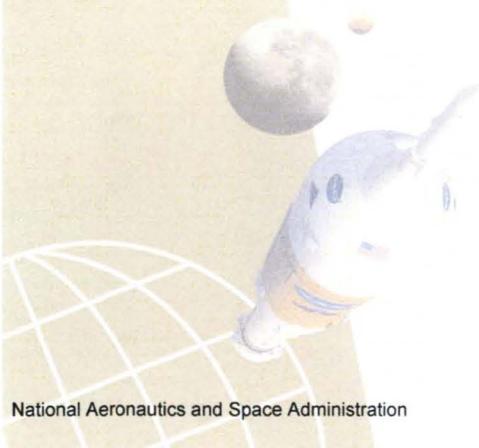




Agenda

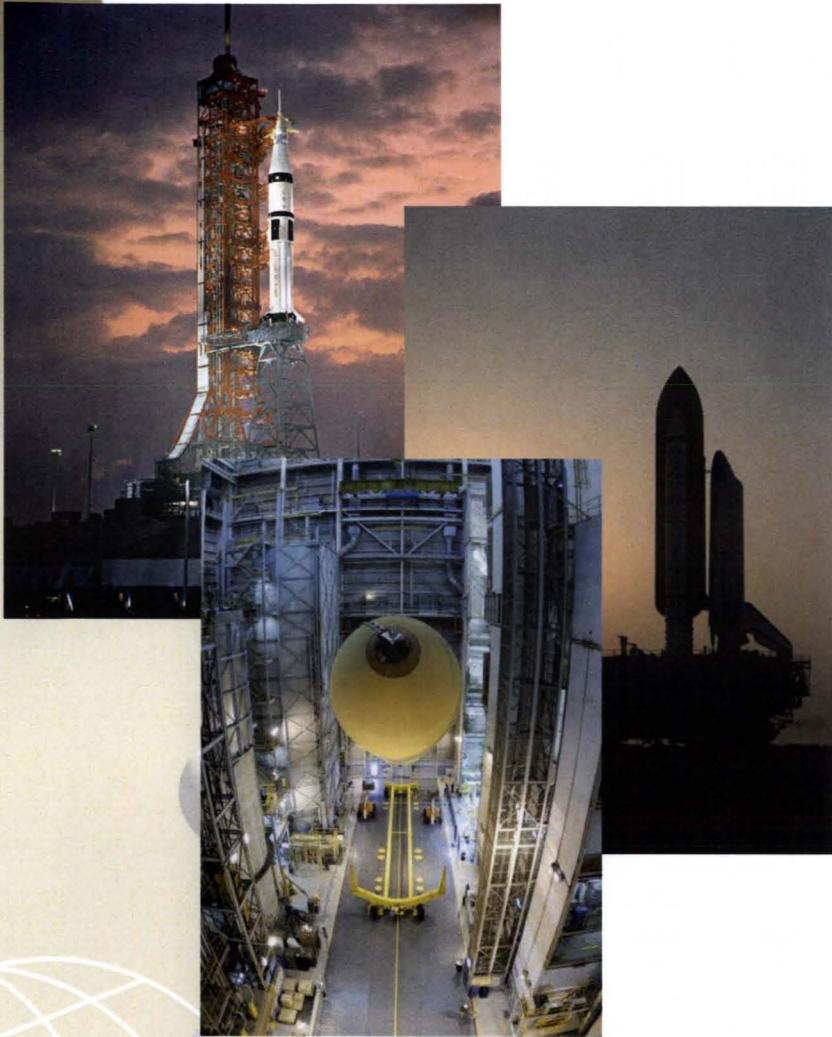


- ◆ **Leveraging Lessons Learned**
- ◆ **Integrating Safety and Mission Assurance (S&MA) into design**
- ◆ **Lean, Kaizen, and Six Sigma Practices in Design and Development**
 - Ares I-X
 - Ares I





Leveraging Lessons Learned



- ◆ **Flying with Launch Abort System / In-line Configuration**
 - Improving chances for escape in emergencies
 - Reducing ascent debris damage threat
- ◆ **Using heritage hardware**
 - Apollo-derived J-2 engine
 - Shuttle solid rocket boosters
- ◆ **Upgrading to new hardware where appropriate (e.g. avionics)**
- ◆ **Using weight-saving measures from ET development**



S&MA Process Changes – Resources



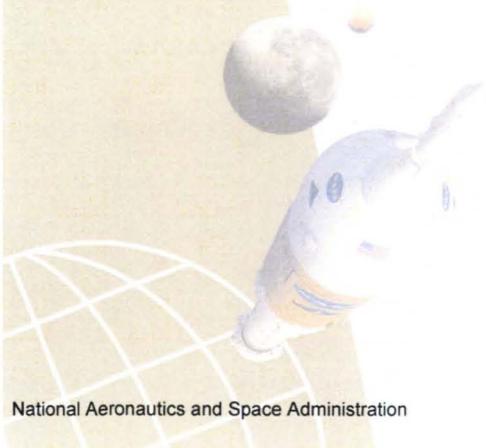
- ◆ S&MA organization elevated from “Office” to “Directorate” level
- ◆ Civil Servant staffing increased from 102 in 2002 to 156 in 2006
- ◆ Project resources still negotiated with the programs and projects – but S&MA given real appeal authority to address shortfalls
- ◆ Resources provided for S&MA Technical Authority, Chief S&MA and others
- ◆ S&MA grade structure brought closer to parity with engineering
- ◆ New S&MA Vision created and communicated
 - S&MA unique discipline expertise
 - S&MAs role of being part of the effort to find solutions
 - Early S&MA involvement leads to improved quality, safety, and reliability of the design
- ◆ Center Director actively championed the rotation of some of the Center’s best engineers into S&MA



S&MA Process Changes – Independence

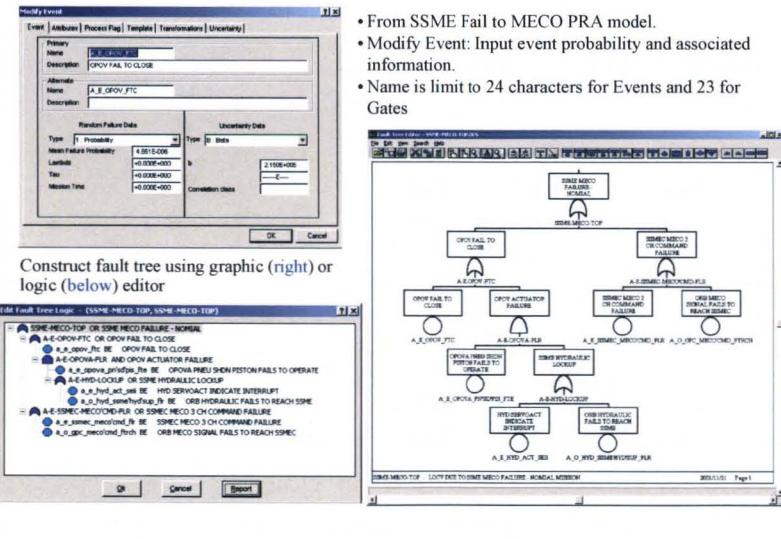


- ◆ **Agency further transitioning to HQ direct funding for S&MA managers designated as part of the technical authority**
- ◆ **S&MA Technical Authority (TA) currently being defined and institutionalized**
 - Will create a healthy balance between S&MA TA, Engineer TA, and Program/Project Management authority
 - S&MA TA will have a seat at every level of management - Level 4 through Level 1
 - Will provide S&MA with the authority to assure S&MA requirements are properly implemented in all programs and projects





S&MA Process Changes – Discipline Expertise

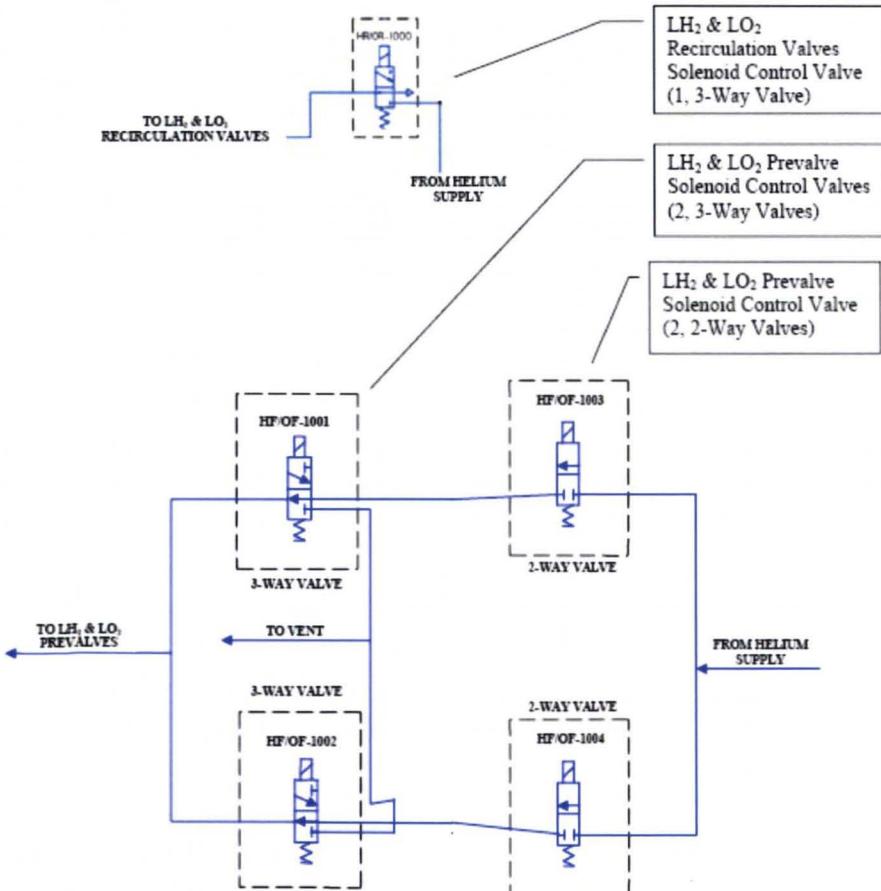


- From SSME Fail to MECO PRA model.
- Modify Event: Input event probability and associated information.
- Name is limit to 24 characters for Events and 23 for Gates

- ◆ All S&MA personnel required to select an S&MA discipline as the primary area of expertise
- ◆ Professional Development Roadmaps (PDRMs) created to identify and list courses, knowledge and the experience necessary to be qualified at the various levels of S&MA discipline development
- ◆ Discipline Champions established to train and mentor S&MA personnel in their efforts to develop
- ◆ Mandatory Discipline working groups established to provide a forum for discipline development and knowledge sharing - run by Discipline Champions



S&MA Value Added – FMEAs



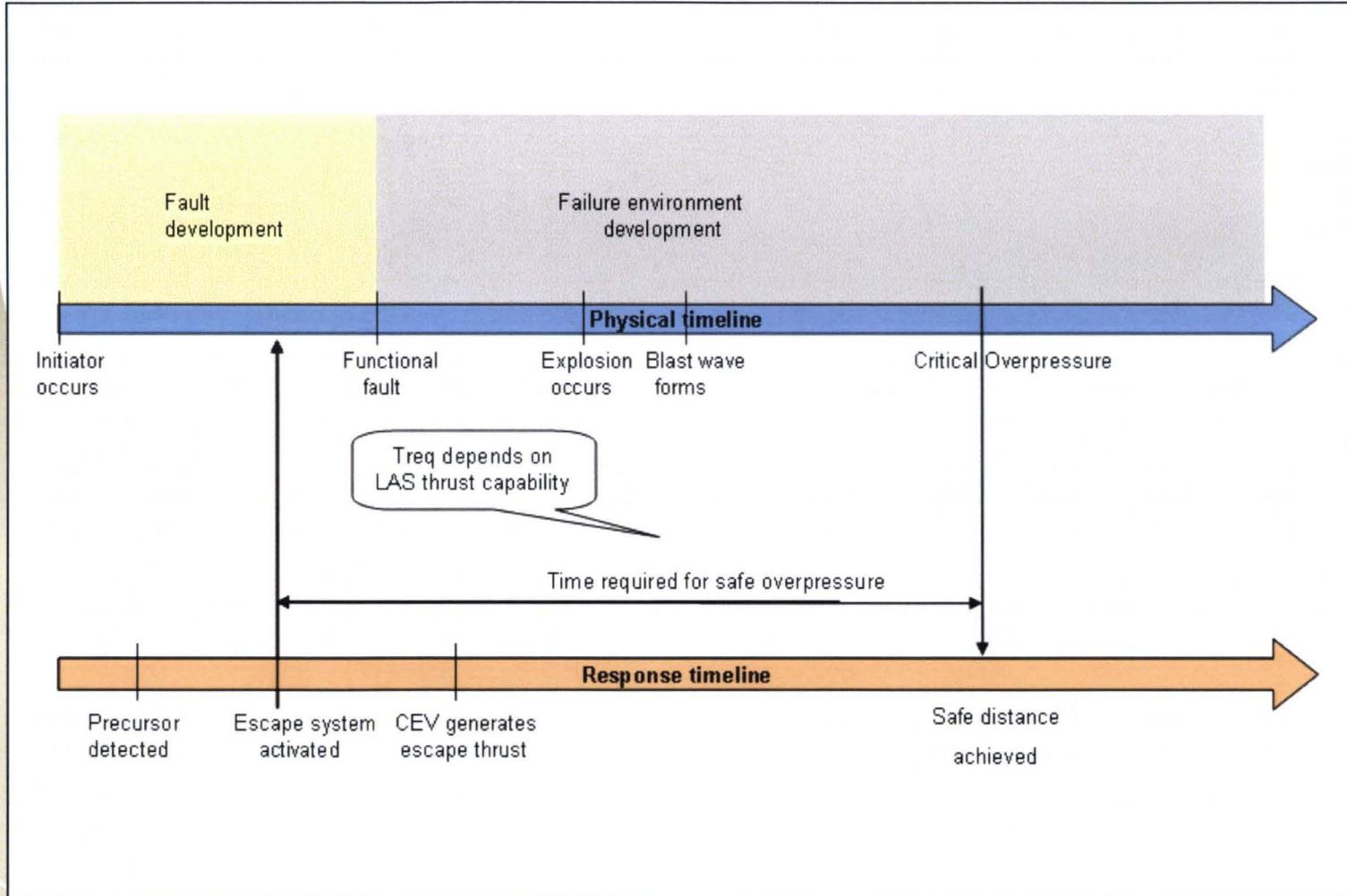
◆ Performed Failure Mode Effect Analysis (FMEA) on design of Pressurization Control Panel

- **Situation:** A proposal was made to reduce the total number of solenoid control valves that control both the J-2X upper stage engine's LH₂ and LO₂ prevalves and recirculation valves to reduce overall cost and weight while increasing the overall system reliability
- A formal reliability trade study was requested to quantify the impact on reliability compared to the baseline design
- The study team examined 4 alternative valve designs that were more fault tolerant
- **Conclusion:** Design alternative 4 was selected because it provided the highest overall system reliability





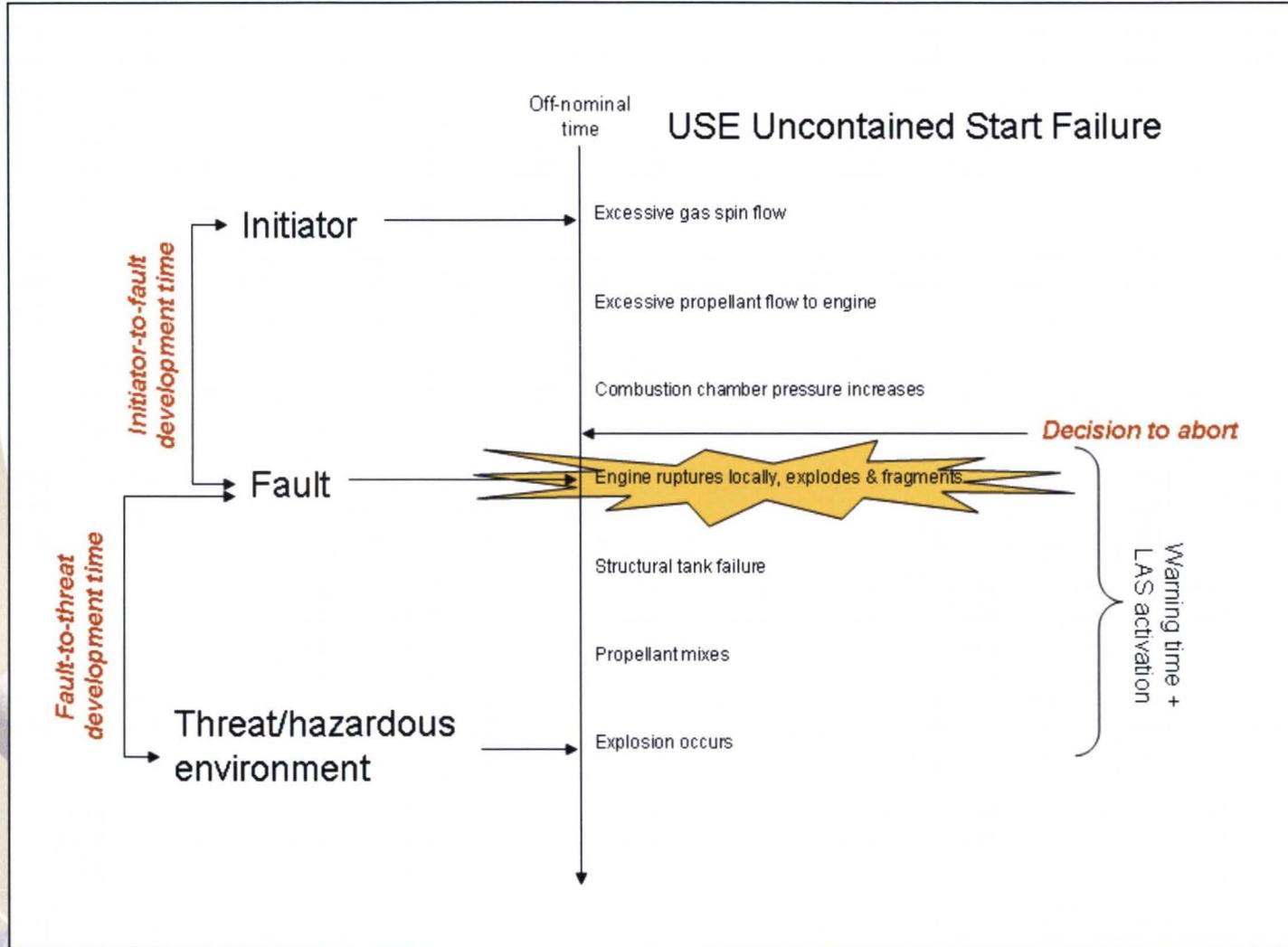
S&MA Value Added – Integrated System Failure Analysis





Integrated System Failure Analysis

Failure Event to Initial Failure Environment

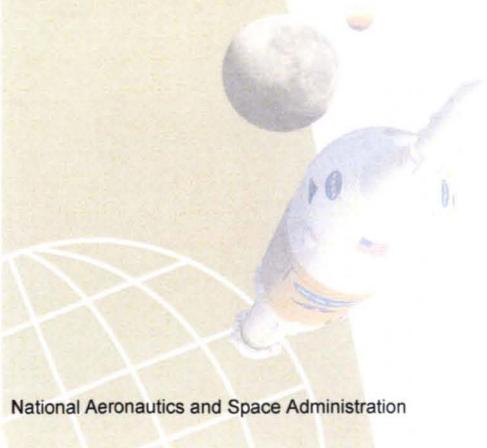




S&MA Value Added – System Safety



- ◆ Recommended move of pressurization line out of the First Stage cable tray to reduce risk to LSC and avionics
- ◆ Influenced common bulkhead monitoring
- ◆ Influenced valve design for LH₂ and LO₂ pressurization to maintain fault tolerance
- ◆ Opened issue for mitigation of overboard GO₂ venting

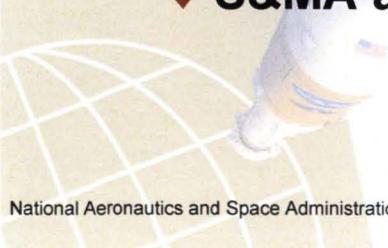




S&MA Value Added – Up-Front Quality Involvement



- ◆ Manufacturing layout
- ◆ Robotic welding tool procurement/acceptance
- ◆ Manufacturing Execution System
- ◆ Drawing Review
- ◆ Phased array ultrasonic weld inspection
- ◆ Workmanship Standards
- ◆ Process FMEA for TPS (in work)
- ◆ S&MA actively engaged in the process





- ◆ **Receiving respect for technical expertise**
- ◆ **Becoming an organization where NASA's best and brightest want to work**
- ◆ **Bringing unique engineering expertise to the table in support of programs and projects**
 - Programs see us as a must-have – not a forced-to-have group – and programs request S&MA support beginning with program formulation
 - S&MA can help make systems safer and more reliable; early recognition of vulnerabilities results in fewer re-design efforts
- ◆ **Actively training and developing its people**
- ◆ **Not only identifying issues, but also helps identify solutions**
- ◆ **Rewarding and acknowledging superior performance**





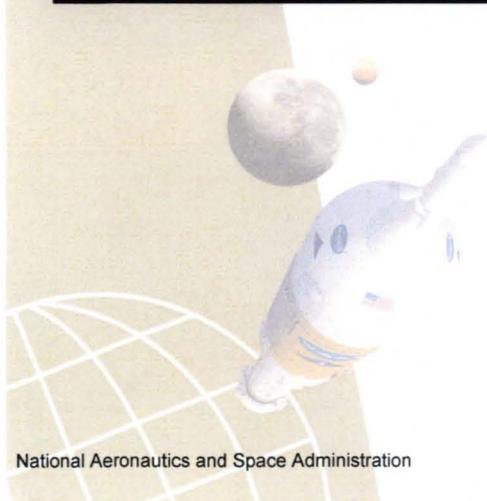
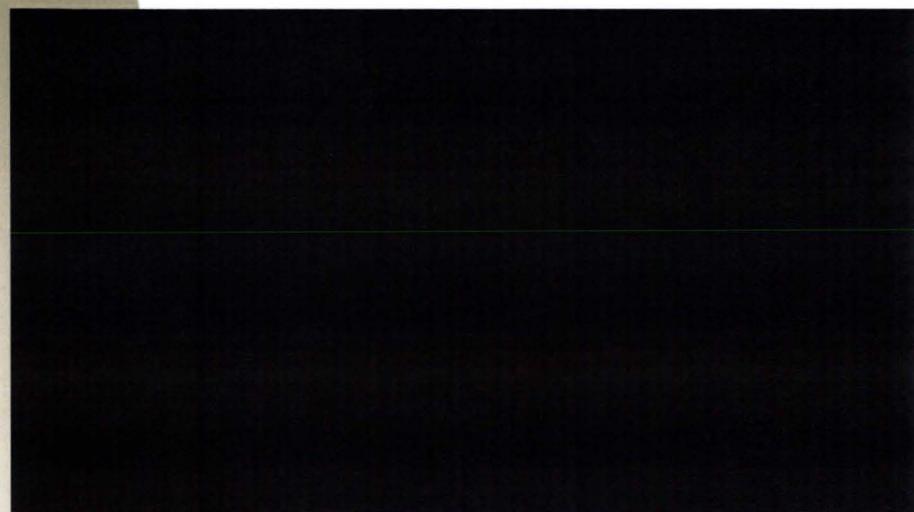
Testing Strategy



- ◆ “Test as you fly” strategy
- ◆ Ground, flight, and orbital tests
- ◆ Ares I-X
 - April 2009
 - Suborbital flight test
 - Combination of operational and mockup hardware
 - Demonstrate ability to control Ares I vehicle
- ◆ Additional Ares tests
 - Ares I-Y: First flight of five-segment RSRB
 - Orion 1: First flight of J-2X and Orion
 - 2015: First crewed flight to International Space Station
 - 2018: First flight of Ares V



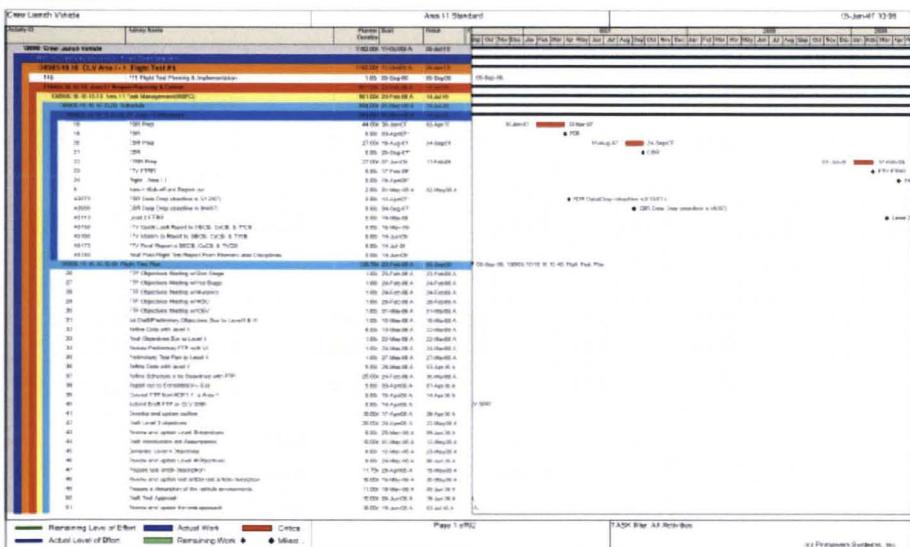
Ares I-X Mission Overview



- ◆ Demonstrate the ascent flight control system
- ◆ Characterize and mitigate the roll torque due to first stage motor performance for a vehicle dynamically similar to the operational vehicle
- ◆ Demonstrate nominal first and upper stage separation and clearances
- ◆ Test the First Stage parachute recovery system and separation/entry dynamics
- ◆ Validate assembly and processing flow, as well as launch and recovery operations



Lean Practices Applied to Ares I-X Schedule



- ◆ Meetings conducted for each vehicle element to incorporate an additional 60 days of schedule margin
- ◆ Events consisted of identifying the following activities:
 - The current state
 - The ideal state
 - A realistic future/target state
 - Assumptions, decisions, and/or actions to be taken to achieve the future state
 - Meeting outputs
- ◆ Assuming 60-day change could be made, Ares I-X MMO managing to the earlier launch date



Lean Practices in Ares I-X



◆ **Identified management need for Lean processes:**

- Different parts of Ares I-X organization had conflicting notions of safety conservatisms in flight test
- **Resolution:** Combined all Ares I-X activities under one Mission Management Office (MMO) under the Constellation Program
- Lean activities also reduced number of review boards by 60%



Lean Event Results



◆ First Stage

- **Actions:** Changed hardware delivery schedule, pre-drilled some hardware for quicker assembly, and deferred avionics testing until the hardware reached Kennedy Space Center (KSC)
- **Result:** Reduced amount of touch-labor time by as much as 4 to 30 days, depending on hardware

◆ Avionics

- **Actions:** Established hard deadlines for delayed items; condensed and reduced number of check points; verified work on-site at KSC; and rescheduled delivery of some components
- **Result:** Met 60-day goal

◆ Roll Control System

- **Action:** Procured support hardware prior to the element's Critical Design Review (CDR)
- **Result:** Met 60-day goal

◆ Upper Stage Simulator / Command Module / Launch Abort System Simulators

- The USS and CM/LAS schedules already supported a 60-day pullback

◆ Ground Systems / Ground Operations

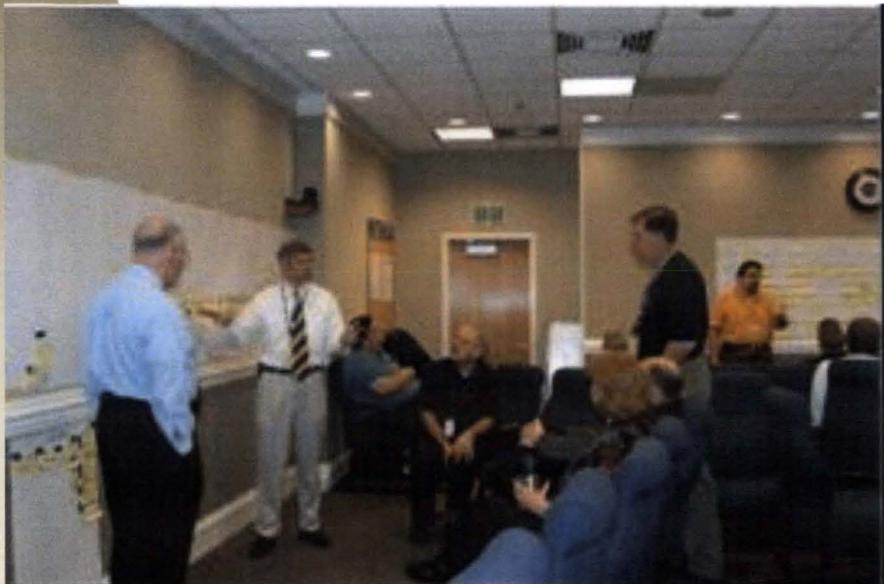
- **Actions:** Streamlined procurement process with United Space Alliance (USA) by reducing the legal review time from 42 to 28 days; reordered activities on the launch pad, reducing pad flow from 7.5 days to 5.5 days
- **Result:** Met 60-day goal

◆ Systems Engineering & Integration

- **Actions:** Streamlined (reduced number of) review cycles for Integrated Design and Analysis, Development Flight Instrumentation, and Assembly Integration and Test
- **Result:** Met 60-day goal

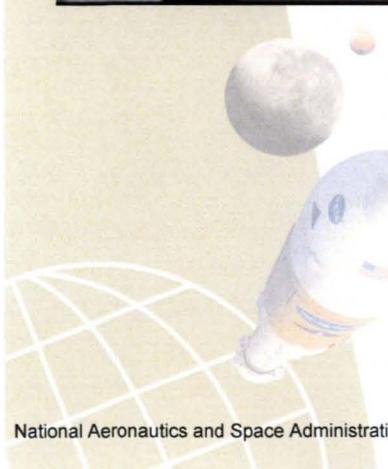


Lean, Six Sigma, and Kaizen Practices in the Ares Projects Office



♦ Leadership commitment

- Ares Projects Office (APO) leaders visited Boeing to learn about 787's market share improvement through lean practices
- APO leaders requested in-house training for all managers on Lean and Kaizen





Lean and Kaizen Success Stories



◆ Lean success stories

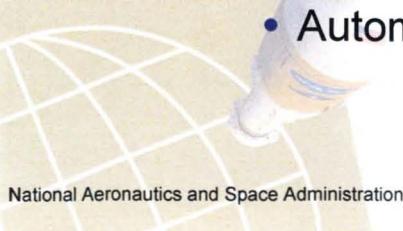
- Integrated Safety & Mission Assurance earlier in design process
- Developing and improving manufacturing processes for Ares I Upper Stage
- Improved communications between vehicle element offices
- Trained Contracting Officer's Technical Representatives on value stream mapping

◆ Kaizen process improvement success stories

- Improved the workforce planning process
- Reduced the length of project integration meetings
- Improved APO's risk management process
- Improved requirements change, trade study, and design review processes

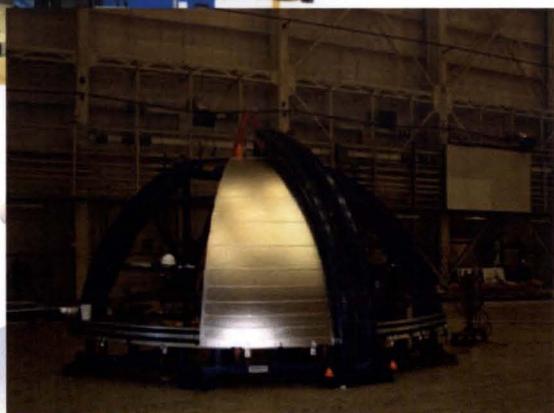
◆ Kaizen new process development success stories

- Optimizing the ground support equipment flow for handling the Ares I Upper Stage
- Merging the manufacturing flows at the Michoud Assembly Facility
- Resolving differences in welding and manufacturing processes between NASA and the Upper Stage prime contractor (Boeing)
- Optimizing the cleaning and corrosion protection processes
- Automating task description sheets





Ares Six Sigma Practices



◆ Ares I Upper Stage Friction Stir Welding Tool

- Uses high rotational speed and frictional heat to crush, "stir" together, and forge a bond between two metal alloys
- At the end of the weld, the single-piece pin tool is retracted and leaves a "keyhole"
- To overcome these drawbacks, a Marshall Center welding engineer helped design an automatic retractable pin tool to prevent keyholes
- Manufacturing and assembly team applied Six Sigma processes to design an experiment to find the optimum machine settings for ensuring a nominal weld
- The analysis developed a set of values for determining the proper settings for welds, as well as determining the effectiveness of a weld if the settings are known but off-nominal
- **Result:** Unprecedented level of accuracy and minimization of weld stress



Ares Team Norms and S&MA Team Messages



Ares Projects Office Team Norms

HAVE FUN

Once in a career opportunity!

We are running a marathon, not a sprint – not in 24/7 emergency mode all the time.

RESPECT OUR FAMILIES AND OURSELVES – HEALTHY BALANCE BETWEEN WORK AND FAMILY IS ESSENTIAL

INTEGRITY IS EXPECTED

"Look each other straight in the eye, tell the truth, full disclosure"

TEAMWORK IS ESSENTIAL

"'Our' instead of 'my', 'We' instead of 'I', 'Us' rather than 'me'... 'we're all important' "

INTEGRATION AMONG THE PROJECT AND WITH PARTNER ORGANIZATIONS (E.G., ENGINEERING, S&MA, OTHER CENTERS, PROGRAM/PROJECTS) IS ESSENTIAL

Communicate, communicate, communicate with each other

Don't wait on someone else to initiate

BELIEVE THE BEST ABOUT EACH OTHER (ASSUME NO MALICIOUS INTENT)

CONSTRUCTIVE CONFLICT LEADING TO DECISIONS (CLOSURE) AND ONCE MADE DON'T CARRY IT PERSONALLY IF IT DID NOT GO YOUR WAY

WE WILL HOLD EACH OTHER ACCOUNTABLE AND MEET OUR COMMITMENTS

Our ultimate commitment is a safe, reliable, affordable delivery of Orion to orbit

FAILURE IS ACCEPTABLE DURING DEVELOPMENT

We are willing to take calculated risks to further our knowledge

EARLY IDENTIFICATION AND HIGHLIGHT OF ISSUES.



◆ Treat others with dignity and respect

◆ Make sure your people have the tools they need to be successful

◆ At the end of the day, make sure that everyone's hard work is acknowledged





S&MA in Ares Design – Summary



- ◆ Providing more resources to support Ares design work
- ◆ Making S&MA more independent for objective assessments
- ◆ Improving discipline expertise as well as training and mentoring opportunities for new employees
- ◆ Adding value through Failure Mode Effect Analyses (FMEAs)
- ◆ Using the Ares quantitative safety and reliability requirement to enforce the “Design for reliability and safety” paradigm shift
- ◆ Improving system safety by using a functional analysis system approach to model and understand integrated system failures similar to the Shuttle foam problem.
- ◆ Improving design reliability by using Probabilistic engineering physics-based modeling
- ◆ Evaluating and understating design uncertainty and design margins using probabilistic engineering techniques
- ◆ Getting involved in quality up front using Lean, Six Sigma, and Kaizen practices
- ◆ Receiving respect for technical expertise
- ◆ Becoming an organization where NASA’s best and brightest want to work
- ◆ Bringing unique engineering expertise to the table in support of programs and projects



Questions?



www.nasa.gov/ares